International Journal of Science and Engineering(IJSE)

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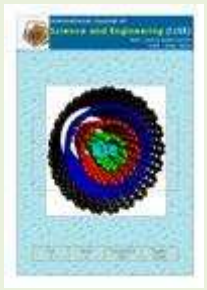

Preparation of Natural Zeolite for Air Dehumidification in Food Drying

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Abstract **-** Drying with air dehumidification with solid adsorbent improves the quality of food product as well as energy efficiency. The natural zeolite is one of adsorbent having potential to adsorb the water. Normally, the material was activated to open the pore, remove the organic impurities, and increase Si/Al rate. Hence, it can enhance the adsorbing capacity. This research studied the activation of natural zeolite mined from Klaten, Indonesia as air dehumidification for food drying. Two different methods were used involving activation by heat and NaOH introduction. As indicators, the porosity and water loaded were evaluated. Results showed both methods improved the adsorbing capacity significantly. With NaOH, the adsorbing capacity was higher. The simple test in onion and corn drying showed the presence of activated natural zeolite can speed up water evaporation positively. This performance was also comparable with Zeolite 3A.

Keywords— *adsorbent, capacity, onion, corn, water loaded*

Submission: 5 February 2015 Corrected : 2 March 2015 Accepted: 19 March 2015

Doi: **10.12777/ijse.8.2.80-83**
[How to cite this article: Djaeni, M., Kurniasari, L., Sasongko, S.B. (2015). Preparation of Natural Zeolite for Air Dehumidification in Food Drying. Internat. J. Sci. Eng. Vol. 8. (2):83 – 84; **Doi**: **10.12777/ijse.8.2.80-83**]

Introduction

Drying with air dehumidification using solid adsorbent such as zeolite, silica and activated clay, is a potential option to improve food product quality as well as energy efficiency [1,2]. With air dehumidification, the driving force for water transfer from solid matrix of a product to the air, can improve. Then, the drying can be faster and more efficient in low or medium temperature in which is suitable for retaining nutrition and active compound in food.

Zeolite has the most potential adsorbent for enhancing food and agriculture drying [1,2]. Zeolite is alumino-silicate compound with tetrahedral bound linked by oxygen. Atom Al is negatif that can be neralized by cation. The exchangable cation affects the adsorption ability of zeolite. Beside that, the ability is also influenced by Si/Al ratio, surface area, and size od zeolite pore [3,4,5]. With high surface area and suitable pore for water (3^{o}A), the capacity of zeolite to adsorb water became higher.

In Indonesia, the natural zeolite is commonly found in the market or mining area. Even, the capacity of zeolite production was high [6]. However, adsorbing capacity of natural zeolite is too low rounding 0.07-0.09 gr water loaded per gr zeolite. In general, the natural zeolite contains organic and an-organic impurities, as well as having high Si/Al ratio. Additionally, the size of pore is not homogenous. For adsorbing water, it needs the size pore 3^{o}A close to molecular diameter of water. Therefore, the activation is required before using natural zeolite [7].

This research discusses comparison of two methods for natural zeolite activation (by heat and NaOH). As material, the natural zeolite obtained from Klaten Indonesia, was used. The aim was to find the zeolite with adsorbing capacity upper 0.10 gr water per gr dry zeolite. After activation, the zeolite was then used for onion and

corn drying. The moisture removal was main indicator to observe the capablity of zeolite for enhancing driving force in the process.

Materials and Methods

This research consisted of two main steps: zeolite activation and agriculture drying with activated zeolite. Activation of zeolite aimed for getting the natural zeolite with affinity of water upper 0.10 gr water per gr zeolite. Two different methods were applied involving activation by heat and alkali. While the agriculture drying was to observe the performance of activated natural zeolite for enhancing the driving force for drying. As materials test, onion and corn were dried with and without zeolite.

Zeolite Activated Heat

Natural zeolite from Klaten Indonesia was activated with two different methods: activation by heat, and NaOH. Firstly, the zeolite was activated by heat. In this step, natural zeolite was weighed 25 gram and heated in autoclave at 200^{o}C for 2 hours. The zeolite was then cooled in desicator. After that, the ability of zeolite for adsorbing water was evaluated in sorption-isotem tank (see Figure 1) at various air condition during 48 hours. The water loaded in zeolite was measured by gravimetry. The method was repeated for various activation time (2-5 hours) and temperature 300-500^{o}C. The best condition was applied to prepare 25 kg of natural zeolite.

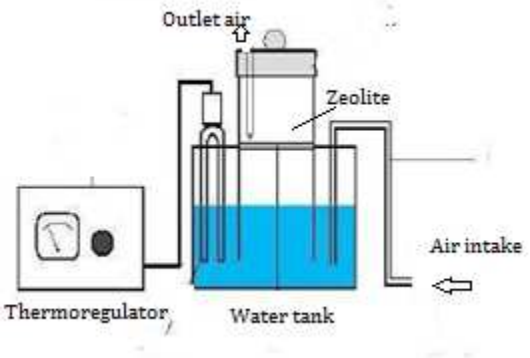

Figure 1. Sorption isotherm for adsorbing capacity test

Zeolite Activated by Heat

The second method involved zeolite activation by NaOH. Here, the zeolite was mixed with NaOH solution (supposed with concentration of 0.5 N). The mixture was stirred under 60^{o}C for 2 hours. After that, the zeolite was washed by water and dried at 110^{o}C for 4 hours. The zeolite was cooled in desicator. The water loaded in zeolite was tested in sorptio-isoterm tank for 48 hours and analyzed by gravimetry. The process was repeated for NaOH 1-2N, and mixing temperature 70-90^{o}C. The best option was used for preparing 25 kg of natural zeolite.

Onion Drying

The activated natural zeolite was used for air dehumidification in onion drying. The convective tray dryer was constructed and completed by zeolite (Figure 2). So, after removing water from the product, the wet air was directly dehumidified by the zeolite. The air temperature and humidity were measured by KW0600561, Krisbow®, Indonesia (noted as T-RH). The air velocity was measured with an anemometer KW0600562, Krisbow ®, Indonesia.

The ambient air was heated up to 50^{o}C by rice husk combusted in furnace. The air passed the dryer to dry 60 kg of onion. The moisture content versus time was observed. The process was conducted for 18 hours until average moisture in onion and leaf close to 75%. The process was repeated for onion drying without zeolite.

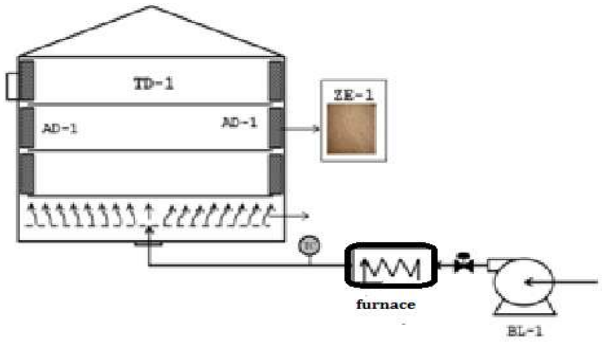

Figure 2. Onion drying with zeolite (Note: TD-1: Tray Dryer, AD-1: Adsorber Box, ZE-1: zeolite, Furnace: Air Heater, BL-1: Blower. The tray dryer dimension was 2.0x1.0x1.6 m)

Corn Drying

In this step, the corn was dried in fluidized bed dryer (see Figure 3). To speed up water evaporation, the amount of zeolite was put in a column (supposed corn to zeolite ratio 1:1). The mixture was fluidized by air at 50^{o}C. The air evaporated water from corn. At same time, the zeolite adsorbed water in air. Hence, the de-sorption (drying) and adsorption was simultaneously conducted in which can improve the driving force for drying. For initial test, the zeolite 3A from Zeochem, Switzerland and natural zeolite activated by KOH were used and compared with drying without adsorbent.

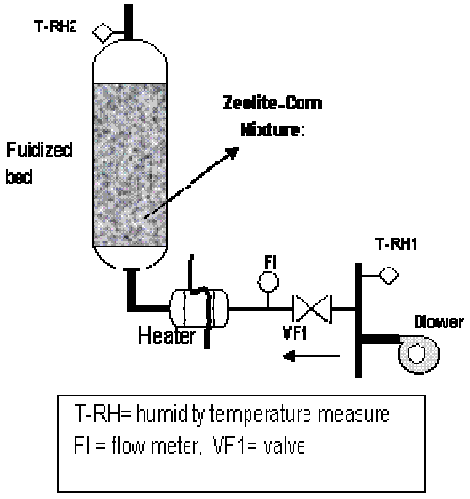

Figure 3. Mixed-adsorption dryer with zeolite (a. process transport, b. operational system)

Results and discussions

Zeolite activated by heat

Activation by heat aimed to remove the organic impurities in zeolite pore. The thermal introduction

caused ion movement in which influenced the pore size [4]. Table 1 presented the water loaded in the natural zeolite after activated by heat. In all cases, the capacity increases significantly (40 – 50% higher than that of the natural zeolite without activation). At activation temperature of 300-400^{0}C for 3 hours, the water loaded in zeolite was 0.137 gr water per gr zeolite. Below 300^{o}C, the organic impurities cannot be totally removed. Therefore, the adsorbing capacity became lower. This result was inline with Turkey's zeolite for activation temperature of 300-400^{o}C [8].

Table 1. Water loaded in the activated zeolite by heat

Activation time of 3 hours				
Temperature (^{o}C)	**200**	**300**	**400**	**500**
Water loaded, gr water per gr zeolite	0.128	0.137	0.136	0.130
Activation temperature of 300^{o}C				
Activation time (hours)	**2**	**3**	**4**	**5**
Water loaded, gr water per gr zeolite	0.130	0.137	0.136	0.135
Natural zeolite without activation 0.08-0.09 gram water per gram zeolite				

Activation by NaOH

Using NaOH silica ion, a componen formating the zeolite crystal was dilluted. This process reduced the Si/Al ratio, then the affinity of zeolite to water increases [9]. In addition, other ion was also substituted by Na^+, so the pore size of zeolite tends to be homogen in the form of homoionic [10]. Table 2 presented water loaded in zeolite activated by NaOH at different concentration and temperature. The water loaded in zeolite can reach 0.171 gr water per gr zeolite after activated for 2 hours under 70-80^{o}C with NaOH 1.0 N. This improvement was quite significant, because natural zeolite can adsorb water 0.08-0.09 gram water per gr zeolite, only.

Table 2. Water loaded in the activated zeolite by NaOH

Activation time of 3 hours				
Temperature ^{o}C	**60**	**70**	**80**	**90**
Water loaded, gr water per gr zeolite	0.145	0.171	0.170	0.167
Temperature of 80 ^{o}C				
NaOH (N)	**0.5**	**1.0**	**1.5**	**2.0**
Water loaded, gr water per gr zeolite	0.155	0.171	0.167	0.160
Natural zeolite without activation 0.08-0.09 gram water per gram zeolite				

Onion Drying

The onion drying was conducted with zeolite and without zeolite under air temperature of 50^{o}C. The result was depicted in Figure 4. The zeolite affected water evaporation during onion drying positively [1,2]. With zeolite, the humidity of air reduced. Hence, the driving force for mass transfer improved. As seen in Figure 4, with zeolite the water in onion became lower for same operational time. However, after long time used, the effectiveness of zeolite decreased. Perhaps, the regeneration during the process was not perfect.

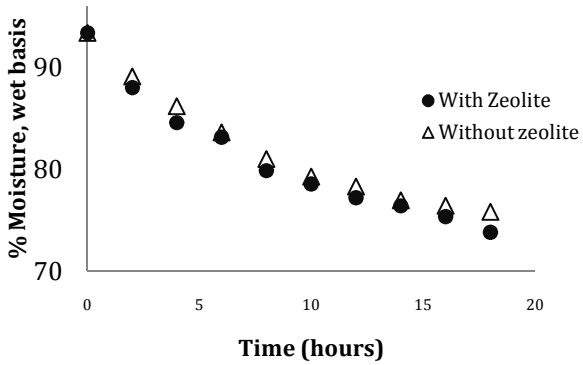

Figure 4. Onion drying with and without zeolite at different dryer temperature for air velocity 0.5 m.s^{-1}

Corn Drying

The effect of zeolite in the corn drying was presented in Figure 5. The corn drying with zeolite required shorter time compared to the that of without zeolite. For example, the drying time to find dry corn with moisture content of 12% (wet basis) was about 90 minutes. In contrast, the corn drying without zeolite needed more than 100 minutes for same level moisture content. Hence, the activated natural zeolite was a good option for improving drying performance. This performance was also comparable with previous results [2, 11].

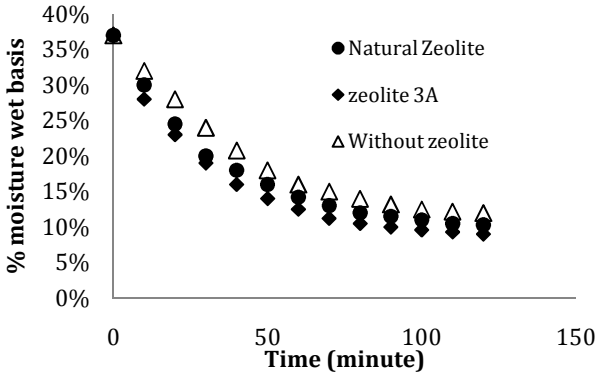

Figure 5. The moisture content versus time at drying temperature 50^{o}C and air velocity 9 m.s^{-1}

Conclusions

Activation of natural zeolite has been done by heating and NaOH. Results showed that the adsorbing capacity of zeolite can reach 0.17 gr water per gr zeolite after activated by NaOH 1.0 N. While, the capacity of water loaded in zeolite after activated by heating at 300^{o}C for 3 hours, was around 0.14 gr water per gr zeolite.

The performance of activagted zeolite was tested for onion and corn drying. Result indicated that the zeolite improved the driving force for drying positively. The

performance of activated natural zeolite was also comparable with corn drying with zeolite 3A.

Ackhowledgement

This research was funded by the Indonesian Directory of Higher Education (DHGE), Ministry of Research and Higher Education, Indonesia. The experimental work was conducted at Department of Chemical Engineering, Diponegoro University.

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